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TIN SOLDERING OF ALUMINUM AND ITS ALLOYS.*

By

Prof. Gino Gallo.

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As is known, aluminum and its alloys can only be welded autogenously or by other very special means, with recourse to fusing and the interposition of alloys with other metals.

Aside from the fact that the autogenous weldings of aluminum and its alloys have intrinsic defects inherent in their nature, like blow-holes, blisters, etc., they cause a deterioration of the mechanical properties of the metal and, in the event of the interposition of other metals, the latter become the seats of electrolytic reactions, with continuous and rapid change, in addition to the other important circumstances that these weldings are only possible between pieces of the same metal alloy and are therefore impossible with other metals. Consequently the field of application of the light metals is necessarily much restricted.

The author considered the possibility of rendering general the joining of the light metals, by having recourse to soft soldering with tin, as practiced with all the other metals.

But, as every one knows, aluminum cannot be soldered in this way, since tin, or the alloy of tin and lead, will not adhere to

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* From "Rendiconti dell' Istituto Sperimentale Aeronautico," February, 1921, pp. 43-50.

A recent article by L Guillet and M. Gasner, published in the "Revue de Metallurgie," (Vol. XVII, 1920, p. 351) on nickel-plating aluminum, influenced me to publish the present article on a process patented by the author in 1916 and which, in its fundamental part, was inspired by the same principle as that adopted by the above-named authors.

its surface. On the other hand, in order to render possible in every instance, the replacement of steel or of other heavy metals with light metals, it was necessary to find the method for joining with soft solder the various members of different structure, which are now employed especially in technical aeronautics, without recourse to profound modifications in the fundamental principles now serving as the basis for such constructions. Herewith, it was possible to obtain automatically any considerable reduction in the dead weight and consequently much increase in the efficiency of the airplane.

The method adopted for solving the problem consisted in the galvanic application to the surface of the light-metal parts to be soldered, of a layer of another metal, which, without re-acting electrolytically on the aluminum, adheres strongly to the surface to which it is applied, and is, on the other hand, adapted to receive the soft solder, thus making it possible to solder together two pieces of aluminum, or to solder aluminum to some other metal, in the ordinary way.

After various trials, it was found that the metal answering these conditions best, as well as being the most economical, is iron. But the electrolytic deposit of this, as well as of other metals, on aluminum, in the form of a uniform and adherent layer, does not give good results with the ordinary methods of cleaning the metal with acids or alkalis.

Only when, instead, recourse is had to a <u>mechanical</u> process of scouring the surface, is a well adhering deposit of another metal on aluminum or its alloys rendered possible, because, under these conditions, the adherence is due exclusively to the "grappling" properties of the metal deposited in the cavities mechanically produced on the surface of the aluminum.

It was found convenient to produce the mechanical abrasion by roughening the metal with emery cloth of medium fineness (No. 0), preferably in two directions normal to each other. After simple washing in running water, it was immediately immersed in the electrolytic bath.*

A suitable electrolytic bath may be prepared by dissolving 20 grams of ammonium oxalate in 500 cc. of hot distilled water, and 10 g. of iron sulphate in another 500 cc. of hot water. The hot solution of iron sulphate is then poured into the solution of ammonium oxalate, giving a volume of one liter, and allowed to cool.

The solution may be used even after it becomes turbid and is only discarded when the electrolytic deposit is no longer satisfactory.

The solution must be prepared and kept in a container of glass or porcelain or enameled iron and must not be left in contact with the iron of the anodes when not in use, since it is no longer serviceable, if it becomes too heavily charged with iron.

The intensity of the current must not exceed 0.5 ampere per

* L. Guillet and M. Gasner, in the work referred to, arrived at the same conclusions and employed a sand blast for roughening, using sand sifted through a sieve with 0.2 mm. meshes, and under a pressure varying from 600 to 1500 grams per sq.cm.

square decimeter of the cathode, with a difference of 4 to 6 volts in potential.

The anode consists of ordinary soft iron. In order to obtain a uniform deposit, it is important for the positive iron electrode to be symmetrical with reference to the piece of aluminum or alloy serving as the negative pole, so as to maintain a nearly uniform distance between the anode and cathode. Thus, for example, in order to deposit iron on the inside of an aluminum tube, it is sufficient to introduce into the latter, as anode, an iron wire, held in place by a cork at the top of the tube. For making a deposit on the outside of a tube, recourse is had to a spiral of the same iron wire outside the tube. Lastly, for objects of various shapes, it is best to make a sheet iron container of a shape similar to that of the object to be plated, in which case the container itself is the positive pole.

When the object of light alloy, to be soldered, can be immersed in the bath with its principal axis vertical and has no outside projections, it can be hung directly in the bath and subjected to the electrolysis. In the case of irregular objects or when they must be immersed horizontally, the precipitate formed in the solution settles on the surface to be plated, thereby preventing, at some points the electrolytic deposit. In this event, there must be a continuous circulation or a suitable agitation of the liquid.

For suspending the object, iron or aluminum wire is used, but never copper. The operation is performed at the ordinary temperature.

When the surface of the cathode has acquired a dull gray iron color, which takes from half an hour to two hours, the piece is removed from the bath, immediately washed in running water and dried by wiping.

If the surface, instead, shows yellow streaks or shiny black spots, or bare spots of aluminum, the operation is not successful, which may be due to a too intense current or to the exhaustion of the solution.

The surface of a light alloy, after being plated in the above manner, can be soldered with tin, either to other pieces of the same metal, treated in the same manner, or to other metals.

For this purpose, the surface of the electrolytic deposit is moistened with hydrochloric acid completely neutralized with zinc, or better by smearing the surface with a thin coat of one of the ordinary soldering pastes existing in commerce.

After this is done, the objects to be tinned are dipped into melted tin (or a soldering alloy of about 40 parts lead and 60 parts tin), until they have acquired the temperature of the bath, and then, if possible, the surfaces to be joined are clamped together until the alloy hardens, without cooling by water. For soldering a soft metal tube to a steel pipe, after immersion in the tin, the steel pipe is pushed inside the tube and allowed to cool.

If, instead, successive solderings must be made, after dipping the surfaces as described, the points to be soldered are moistened with spent hydrochloric acid or with paste, and the soldering is then done with a blowpipe or gasoline torch with the application of ordinary soldering alloy.

When the soldering has been well done, it will withstand a pull equal to that of soldered iron.

If the surfaces are to be simply tinned, it is sufficient to immerse them, after pickling, in melted tin and then wipe off the excess tin with a rag.

The results of these experiments were summed up in a patent granted in Italy, May 18, 1916, and extended successively in France England, Belgium, America and Japan.

The accompanying illustrations show some of the results easily obtained by this process of soldering: the construction of a framework consisting of parallel tubes of light metal connected by an obliquely bent tube of another metal (Fig. 1) and how it is possible to solder tubes of light metal to steel pipes (Fig. 2). In the latter case, an innovation was introduced by the writer in the method of attaching the tubes to the pipes, in that the tube of light metal surrounds the steel pipe and not inversely, as had been the custom. The tube, forced on by compression, rests against a suitable shoulder on the outside of the pipe, so that, after it is on, it forms a continuous surface, with the consequent elimination of any projection, as in ordinary unions which, on account of the great speed now attained by airplanes, exert considerable influence on the head resistance. This method of joining also has another advantage. On account of the larger coefficient of expansion of aluminum in comparison with steel, the aluminum, which is expanded more by the heat required for soldering, hugs the steel pipe harder on cooling and thus assures a still better adhesion. In fact, tensile tests with 30 x 27 mm. tubes of light metal, with a breaking strength of 48 kg. per sq.mm. and a ductility of 12%, soldered in the above manner for a distance of 30 mm. to pipes of 0.5 mm. steel, resulted in tearing the steel pipes, instead of separating the soldered parts.

For illustrating some applications of this method of soldering in the field of aeronautics, we can show how, by this process, it is possible and easy, without fundamental modifications of the present construction methods, to substitute light metals for other materials in constructing, for example, the framework of airplanes and airships, in soldering sheet metal for the cockpits, in making and repairing crankcases, and, lastly, instead of wood, for wing spars and ribs with suitable sections for increasing their moment of inertia, improving the penetrating properties of the machine and reducing the head resistance from friction to a minimum.

In Figs. 3 and 4 is shown an airship girder made of duralumin tubing and braced with iron tubing, tin soldered by the method in question and then subjected to compression tests.

The principal characteristics of this girder, in comparison with a similar girder of steel tubing, are given in the following table:

Characteristics	Girder of duralumin tubing with braces of steel tubing; tin soldered.	Girder of all steel tubing with braces of steel tubing; tin soldered.
Shape of girder	Equilateral triangle 200 mm. on a side	Equilateral triangle 200 mm. on a side
Main tubes	Duralumin, 30 x 1.2 mm.	Steel, 30 x 0.5 mm.
Bracing tubes	Steel, 10 x 1 mm.	Steel, 10 x 1 mm.
Length of girder	4 m.	4 m.
Total weight of girder	5.95 kg.	8.47 kg.
Weight per running meter	1.49 kg.	2.12 kg.
Breaking strength by compression	6190 kg.	5875 kg.

Lastly, the possibility of covering aluminum and its alloys with a uniform coating of tin is of considerable practical importance. It is known that when two different metals come in contact with each other in the same solution, there is established between them a difference of potential, just so much the greater as the metals themselves are more distant from each other in the so-called electro-chemical series of the elements, which begins at the positive end with the alkaline metals and then becomes negative toward the non-metals. Given thus, the following electro-chemical series of the elements:

K	+	[illegible]	Volt	Fe	+	0.09	Volt	Sb	-	0.38	Volt
Na	"	[illegible]	"	Co	-	0.02	"	Bi	"	0.50	"
Mg	"	1.24	"	Ni	"	0.02	"	As	"	0.55	"
Al	"	1.03	"	Sn	"	0.09	"	Cu	"	0.59	"
Mn	"	0.82	"	Pb	"	0.10	"	Hg	"	1.03	"
Zn	"	0.51	"	H	"	0.25	"	Ag	"	1.06	"
Cd	"	0.16	"								

it is observed that aluminum and copper are very far from each other and, while aluminum is strongly electropositive, copper is electronegative. It follows, therefore, that whenever aluminum comes in contact with copper or any alloy of copper in the presence of any solution, which may even be simply the moisture in the air, an electrolytic couple is formed, in which the aluminum functions as the positive pole, that is, as the soluble metal, and will (as likewise its alloys) undergo rapid corrosion. This fact has been confirmed many times in practice, in cases of simple contact of an alloy of aluminum with brass or bronze.* It attained considerable proportions when the metallic contact took place in the presence of sea water. Now, covering aluminum (or one of its alloys) with a strongly adhering coat of tin, asby this process, completely eliminates this harmful electrolytic action, since tin is electronegative, like copper, and these two metals do not react electrolytically on each other. It is accordingly necessary to take account of these phenomena in practice and of the possibility of using the light metal, even in contact with copper alloys, when the light metal has been properly tinned.

* Aluminum radiators, supported on bronze brackets, have, in some cases, been completely perforated. Aluminum fuel tanks with brass plugs rapidly corrode at the points of contact.

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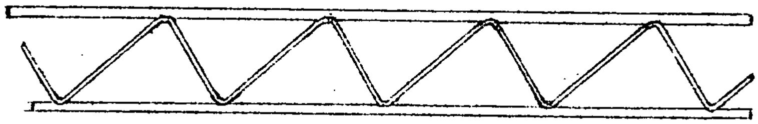

Fig. 1.

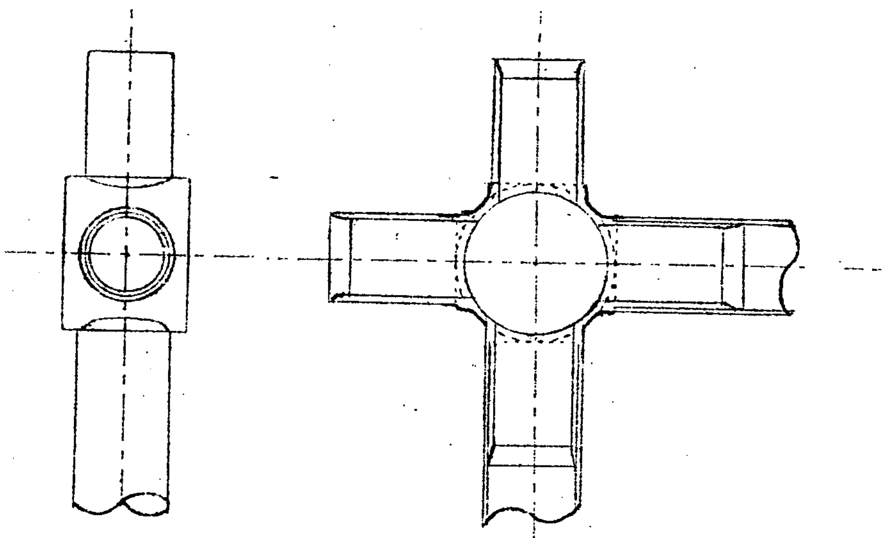

Fig. 2.

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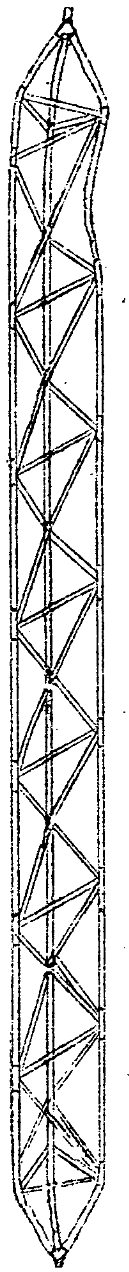

Fig.3.

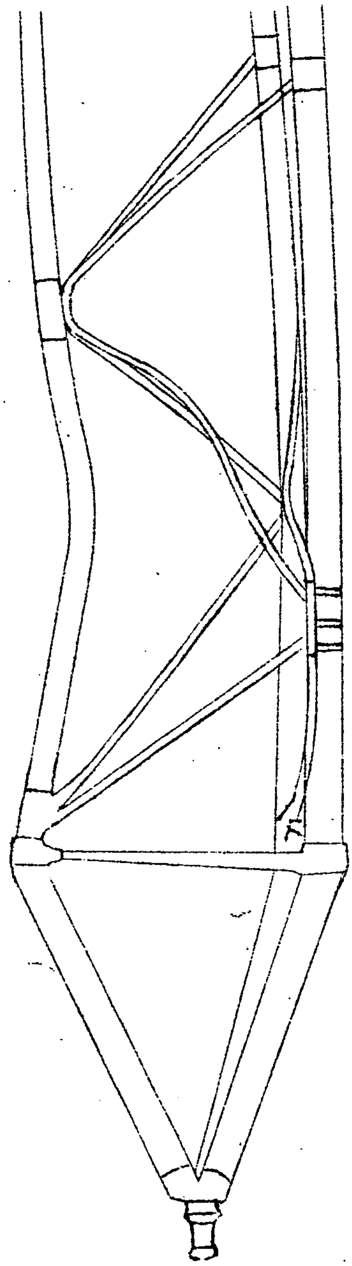

Fig. 4.